PATENT SPECIFICATION

DRAWINGS ATTACHED

922,873

Date of Application and filing Complete Specification Sept. 28, 1960 No. 33312/60.

Application made in United States of America (No. 848704) on Oct. 26, 1959.

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Index at acceptance:—Classes 35, A(5X:8D2); and 36, A1C, A2E(2A:3D1:3D2:4C), A3(E:H:M).

International Classification:—H02k (H01b).

COMPLETE SPECIFICATION

ERRATUM

SPECIFICATION No. 922,873

Page 1, in the title, *for* "Insulator" *read* "Insulation"

THE PATENT OFFICE
30th August 1963

machines, the individual conductors after being insulated are placed together in a non-transposed or transposed fashion as required, with an insulating separator between each stack of conductors. When transposing the conductors to reduce skin losses, the voids thereby left in the periphery of the bar are filled by an insulating material.

Many insulating materials have been used for the outer or ground insulation of electrodynamic machine windings. Among such insulating materials have been various combinations of mica flake tape impregnated with an asphaltic or bitumen material. However, such ground insulation has a rather limited resistance to elevated temperatures. Of particular interest is ground insulation consisting of the organopolysiloxane or silicone materials which in general are characterised not only by good electrical insulating qualities but by flexibility and resistance to high temperature.

A principle object of this invention is to provide an insulating covering for electrodynamic machine conductors which is

[*Price* 4*s*. 6*d*.]

conjunction with the accompanying drawing, in which the single figure is a perspective cross-sectional view of a typical insulated bar of the invention.

The strand insulation or inter-strand insulation of conductors used in connection with this invention must be chosen from materials which are resistant to temperatures up to 200° C., this being necessary to cure the ground insulation and, more particularly, the organopolysiloxane content of the ground insulation. The selected strand insulation has as its resinous component epoxy resin compositions of particular characteristics. The epoxy resins in general are well known in the art. They are described in British Patent No. 518,057 and British Patent No. 579,698.

Such ethoxyline resins are sold under the name of Epon by Shell Chemical Corporation, under the Registered Trade Mark Araldite by the Ciba Company, as Epi-Rez by Devoe-Raynolds Company and as ERL resins by the Bakelite Company.

In preparing the strand insulation or the insulation 2 on the individual conductor

Price 7/-

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COMPLETE SPECIFICATION

Insulator for Electrical Conductors

We, GENERAL ELECTRIC COMPANY, a Corporation of the State of New York, United States of America, having its office at Schenectady 5, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to new and useful insulating materials for electrical conductors, and especially for electrodynamic machine windings, which are characterised by improved strength.

Windings for electrodynamic machines are generally constructed of a plurality of conductor turns or strands, or both, insulated from each other and having a surrounding or outer ground insulation. In alternating current machines, the individual conductors after being insulated are placed together in a non-transposed or transposed fashion as required, with an insulating separator between each stack of conductors. When transposing the conductors to reduce skin losses, the voids thereby left in the periphery of the bar are filled by an insulating material.

Many insulating materials have been used for the outer or ground insulation of electrodynamic machine windings. Among such insulating materials have been various combinations of mica flake tape impregnated with an asphaltic or bitumen material. However, such ground insulation has a rather limited resistance to elevated temperatures. Of particular interest is ground insulation consisting of the organopolysiloxane or silicone materials which in general are characterised not only by good electrical insulating qualities but by flexibility and resistance to high temperature.

A principle object of this invention is to provide an insulating covering for electrodynamic machine conductors which is characterised by improved electrical qualities as well as by adequate thermal and physical qualities.

Briefly stated, the invention provides an insulated electrical conductor bar, comprising a number of individual strands insulated by means of an epoxy resin compound which surrounds them and fills the spaces between them, said epoxy resin composition containing a fibrous material selected from asbestos, glass, polyethylene-terephthalate and combinations of these, the assembly being enclosed in an insulating layer of epoxy-resin-bonded mica flake, mica paper or asbestos-glass sheet material, and having an additional layer of organopolysiloxane material applied to the exterior.

The invention will, however, be better understood and appreciated from a consideration of the following description taken in conjunction with the accompanying drawing, in which the single figure is a perspective cross-sectional view of a typical insulated bar of the invention.

The strand insulation or inter-strand insulation of conductors used in connection with this invention must be chosen from materials which are resistant to temperatures up to 200° C., this being necessary to cure the ground insulation and, more particularly, the organopolysiloxane content of the ground insulation. The selected strand insulation has as its resinous component epoxy resin compositions of particular characteristics. The epoxy resins in general are well known in the art. They are described in British Patent No. 518,057 and British Patent No. 579,698.

Such ethoxyline resins are sold under the name of Epon by Shell Chemical Corporation, under the Registered Trade Mark Araldite by the Ciba Company, as Epi-Rez by Devoe-Raynolds Company and as ERL resins by the Bakelite Company.

In preparing the strand insulation or the insulation 2 on the individual conductor

strands 1, usual insulating techniques are used which are well known to those skilled in the art. Normally, the wire is coated with the resin varnish containing a curing agent; asbestos fibres, or other suitable fibrous materials, i.e., glass, polyethyleneterephthalate, or combinations thereof, are applied thereto; and these fibres are in turn impregnated with the resin varnish, any excess of the resin being removed by wipers. Of course, pre-impregnated tapes can also be used. The material is also heated to expel all volatile material such as solvent, and may be left in the uncured state or treated to obtain a partial or full cure. Typical epoxy resin solutions which have been found useful for this strand insulation are those comprising from 10 to 20 per cent Epon 1310, 60 to 80 per cent Araldite 6010, 0.2 to 10 per cent tetrabutyl-titanate, 0.1 to 6 per cent dimethyl soya amine, and 5 to 15 per cent methyl ethyl ketone. Upon 1310 is the polyglycidyl ether of 1,1[1], 2,2[1]-tetrakis (hydroxyphenyl) ethane. A preferred epoxy resin solution for such use is one containing, by weight, 14 per cent Epon 1310, 71.4 per cent Araldite 6010, 4.3 per cent tetrabutyl titanate, 1.5 per cent dimethyl soya amine, and 8.8 per cent methyl ethyl ketone. It will be realized, of course, that in place of the methyl ethyl ketone, any of the other well known solvents for epoxy resins may be used, so long as they are compatible. Other well known epoxy resins useful for this purpose will occur to those skilled in the art.

The vertical separators 3 are readily made by impregnating an asbestos-glass cloth or paper of the usual type with an epoxy or other resin solution as by dipping, brushing, or application through coating rollers, the finishing material then being completely dried but with no polymerization taking place. Typical epoxy resin solutions for vertical separator treatment are those containing, by weight, from 35 to 65 per cent Epon 1310, 10 to 20 per cent Araldite 6010, 0.2 to 10 per cent tetrabutyl titanate, 0.1 to 6 per cent dimethyl soya amine, and 30 to 60 per cent methyl ethyl ketone, while a specifically preferred material is one containing, by weight, 41.7 per cent Epon 1310, 13 per cent Araldite 6010, 2.7 per cent tetra-butyl titanate, 1.1 per cent dimethyl soya amine, and 41.5 per cent methyl ethyl ketone. Other epoxy and polyester compositions, well known to those skilled in the art, can be used.

Whereas in D.C. machines, the entire conductor bar array is made up of conducting material or strands, in A.C. machines it has been found desirable in some cases, as pointed out above, to transpose the strands by one means or another as, for example, when there is accomplished a complete shifting of the respective strand positions throughout the conductor bar length. The voids or spaces produced in the vertical ends of the conductor bars indicated at 4 in the drawing, which were formerly filled with a shellac or asphalt impregnated fibrous material are preferably filled with a so-called putty or filler. This may have as its base a silicone rubber formulation, a polyester of the usual type or an epoxy resin. It will be understood, of course, that the foregoing description of the strand insulation is by way of illustration for the purpose of presenting an exemplary type of such insulation.

It has been found unexpectedly that much greater electrical strength may be obtained in the ground insulation system when the first layer of insulating material or that adjacent the conductor bar is composed of a resin-bonded mica flake or mica paper material (or alternatively a resin-bonded sheet material made up of asbestos and glass). The resins used for bonding this layer are epoxy resins, such as those described above. Typically, this mica-containing layer 5 may consist of a backing layer of glass fabric about one mil in thickness mounted upon which are mica flakes or mica mat of about 4 to 10 mils thickness and superimposed thereon another one mil layer of glass fabric. Typically, the content of the mica tape is about 30 per cent resin, 65 per cent mica and about 5 per cent solvent. It will be realized, of course, that other proportions of resin to mica may be used and that mixtures of mica flakes and mica paper can be utilized as well as these materials alone. Likewise, the total thickness of the tape can be adjusted as desired. For example, while the thickness is typically from about 6 to 8 mils thicknesses, up to about 17 mils or even greater are entirely feasible and practical as required.

The mica tape as described above is wrapped in an unreactive tape and then subjected to vacuum treatment. It is afterwards pressure cured in a hydraulic fluid such as molten bitumen under temperatures and pressures which will vary according to the particular resin used, but which are of the order of 100 psi and about 160° C. Typically, the evacuating stage lasts for about 9 hours and the pressurizing-curing for about four hours.

The purpose of this vacuum-pressure procedure is to remove volatiles from the resinous components of the bar structure and cure the resin binder of the mica tape layer to the point where it will not interfere with the vulcanization of the overlying organopolysiloxane ground insulation layer.

There is applied over the mica-containing layer a series of layers 6 of silicone rubber tape. While the invention is described in connection with particular organopolysiloxane ground insulation, it will be realized that suitable organopolysiloxanes in general may be

used in connection therewith, the improved electrical strength obtained by the practice of the invention not being limited to any particular ground insulation but more to the presence of the mica-containing layer next to the conductor. In this connection, it is pointed out and it is believed that the improved electrical strength is attributable to the mica layers being constructed of platelets or flakes of mica so that no direct radial path for the outward flow of electrons or ions is available, such outward flow being blocked by the overlapping nature of the bonded mica within the layer. A similar mechanism is believed to be operable in the case of asbestos-glass fibre material.

The organopolysiloxanes used for the silicone rubber tape may be methylvinylpolysiloxanes, which are prepared typically by reacting octamethylcyclotetrasiloxane and tetramethyl-tetravinyl-cyclotetrasiloxane in such proportions that the vinyl polysiloxane gum contains about 0.2 per cent vinyl groups on the polysiloxane chain with 0.01 per cent by weight KOH at a temperature of about 140° C. to 150° C. for 4 or 5 hours. One hundred parts, by weight, of this material are then doughmixed at 110° C. to 115° C. for one hour with 3 parts, by weight, diethylene glycol bis-(2-n-butoxyethyl carbonate) and 40 parts, by weight, finely divided silica filler. (Diethyl carbonate can be used as the carbonate.) There are mixed in after this doughmixing two parts by weight benzoyl peroxide and the methylvinyl compound so prepared is soluble in benzene and has an average of about two methyl groups per silicon atom. This methylvinylpolysiloxane is convertible to the cured, solid, elastic state, and there is usually therewith a structure-reducing additive comprising an organic carbonate in amounts ranging from 0.05 to 10 per cent, by weight, based on the weight of the convertible organopolysiloxane. The alkylarylvinylpolysiloxanes may also be used and these can be made, for example, by mixing octamethylcyclotetrasiloxane in the amount of 100 parts, by weight, with 15 parts of octaphenylcyclotetrasiloxane and heating to about 130° C., thereafter adding 0.023 part 1,3,5,7-tetramethyl - 1,3,5,7 - tetravinyl cyclotetrasiloxane to the mixture with about 0.01 per cent, by weight, KOH, based on the total weight of the organopolysiloxanes, the mixture then being heated for about 5 hours with stirring at 16° C. to 175° C. The KOH is then neutralized as with trichloroethyl phosphite at 175° C. and devolatilized to produce a methyl phenyl silicone containing an average of about two organic groups to each silicon atom. This material is typically mixed in the amount of 100 parts, by weight, with about 4 parts of diphenylsilanediol, and about 40 parts of finely divided silica over a period of about 2-1/2 hours to insure smooth and complete blending of the filler with the polymer mix, this mixing being accomplished in a Banbury mixer, doughmixer or equivalent apparatus at a temperature of about 140° C. to about 180° C. After cooling to room temperature, one part of bis-(2,4-dichlorobenzoyl) peroxide is added while mixing on a rubber mill. This organopolysiloxane tape is of the unsupported type and utilizes the above methylvinylpolysiloxanes and alkylarylvinylpolysiloxanes, one being used as a backer with the other being used as the adhesive. The tape is formed in a manner well known to those skilled in the art, being typically formed on calender rolls with or without a thin film carrier as required. The backer is formed first and is cured, after which the adhesive material is applied in a semi-cured condition to the backer. Typically, about five or six half-lapped layers of unsupported silicone rubber tape are wrapped over the mica-containing layer, the tape being typically wound in half-lapper fashion, the whole being surrounded by an armour layer 7 of glass fabric or glass-polyethyleneterephthalate fabric coated with an organopolysiloxane such as above. The outer reinforced layer may also contain various percentages of conducting materials, such as carbon black or silicon carbide, said conducting composite serving to electrically grade the system. The wrapped bar is then typically moulded in a press for about 20 to 30 minutes and 50—800 psi pressure, a layer of polyethyleneterephthalate sacrifice tape being first placed on the stator bar and removed after vulcanization. In addition to moulding the wrapped bar, vulcanization may be effected by the use of vacuum-pressure techniques heretofore mentioned using molten bitumen, fluids or steam as a means of obtaining heat and pressure, or the use of heat shrinkable tapes may be employed with a suitable heat source, or bag moulding techniques known to the art. The insulated bar is then cured for times ranging up to about 24 hours at temperatures ranging from 100° C. to 200° C. The selection of curing schedule is related to the maximum designed service temperature of the insulation. In general, it has been found satisfactory to expose the organopolysiloxane materials to a freely circulating air oven at temperatures of 50° C. in excess of maximum hot spot temperatures in order to stabilize the insulation by eliminating reactive volatiles.

In lieu of the two-component non-reinforced silicone tape ground insulation described above, reinforced silicone rubber tape may also be used. For example, in place of the unsupported silicone rubber tape, there was used a tape having as a reinforcing layer glass-polyethyleneterephthalate tape, the glass yarns constituting the fill of the tape and the polyethylene glycol terephthalate the warp thereof, the tape being coated and impregnated with

the organopolysiloxane as before. The method of application and curing of the reinforced organopolysiloxane tape is essentially the same as that used with the non-reinforced tape. Other reinforcing materials may be derived from the class of glass cloths, polyethylene-terephthalate cloths and other common reinforcing fabrics known to those skilled in the art.

It will be realized, of course, that while the organopolysiloxanes of the present invention are described as being in tape form which is later fused to a unitary mass, the organopolysiloxane may in typical cases be applied by moulding or extruding the organopolysiloxane on the conductor or by applying organopolysiloxane which, upon being cured, remains in discrete layers which are bound together by suitable adhesives well known to those skilled in the art.

As pointed out above, an armoured insulating layer 7 may be applied over the organopolysiloxane layer 6 if extra protection, physical abrasion and the like are desired. Typically, this armoured layer consists of a layer of glass or glass-polyethylene terephthalate tape, the glass yarns constituting the fill of the tape and the terephthalate the warp thereof. This tape can be coated with any desired rubber or resin, with or without conducting filler, typically with an organopolysiloxane such as those described above. The armour tape usually is cured at the same time as the underlying organopolysiloxane tape.

The present invention provides methods of insulating electrical conductors which are characterized by giving superior electrical strength such as is required in modern electrodynamic machines. They are resistant to the high temperatures which normally occur in electrodynamic machines.

WHAT WE CLAIM IS:—

1. An insulated electrical conductor bar, comprising a number of individual strands insulated by means of an epoxy resin compound which surrounds them and fills the spaces between them, said epoxy resin composition containing a fibrous material selected from asbestos, glass, polyethylene-terephthalate and combinations of these, the assembly being enclosed in an insulating layer of epoxy-resin-bonded mica flake, mica paper or asbestos-glass sheet material, and having an additional layer of organopolysiloxane material applied to the exterior.

2. An insulated conductor bar according to Claim 1, in which the organopolysiloxane material is in the form of a silicone rubber tape.

3. An insulated conductor bar according to Claim 1, in which the organopolysiloxane is a methylvinylpolysiloxane.

4. An insulated conductor bar according to Claim 1, in which the organopolysiloxane is a methylphenylvinylpolysiloxane.

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922873 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale